

# Document made available under the Patent Cooperation Treaty (PCT)

International application number: PCT/US05/005358

International filing date: 22 February 2005 (22.02.2005)

Document type: Certified copy of priority document

Document details: Country/Office: US  
Number: 60/558,287  
Filing date: 31 March 2004 (31.03.2004)

Date of receipt at the International Bureau: 17 March 2005 (17.03.2005)

Remark: Priority document submitted or transmitted to the International Bureau in compliance with Rule 17.1(a) or (b)



World Intellectual Property Organization (WIPO) - Geneva, Switzerland  
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**APPLICATION NUMBER: 60/558,287**

**FILING DATE: *March 31, 2004***

**RELATED PCT APPLICATION NUMBER: *PCT/US05/05358***



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# PROVISIONAL APPLICATION FOR PATENT COVER SHEET

This is a request for filing a PROVISIONAL APPLICATION FOR PATENT under 37 CFR 1.53(c).

Express Mail Label No. ET558176852US

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## TITLE OF THE INVENTION (500 characters max)

METHOD FOR CONSTRUCTING A GEOLOGIC MODEL OF A COMPOSITE SEDIMENTARY BODY

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## ENCLOSED APPLICATION PARTS (check all that apply)

☒ Specification Number of Pages

21

☐ CD(s), Number

☒ Drawing(s) Number of Sheets

5

☐ Other (specify)

☒ Application Data Sheet. See 37 CFR 1.76

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05-1328

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331.04

REGISTRATION NO.

46,099

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PROVISIONAL APPLICATION FOR PATENT under 37 CFR 1.53 (C)

## **METHOD FOR CONSTRUCTING A GEOLOGIC MODEL OF A COMPOSITE SEDIMENTARY BODY**

### **FIELD OF THE INVENTION**

[0001] This invention relates generally to the field of geophysical prospecting. More specifically, the invention is a method for constructing a geologic model capable of specifying the internal structure and grain size distribution within a composite sedimentary body, based on a seismic image of the body.

### **BACKGROUND OF THE INVENTION**

[0002] In the oil and gas industry, seismic prospecting techniques commonly are used to aid in the search for and evaluation of subterranean hydrocarbon reservoirs. A seismic prospecting operation consists of three separate stages: data acquisition, data processing, and data interpretation. The success of the operation depends on satisfactory completion of all three stages.

[0003] In the data acquisition stage, a seismic source is used to generate an acoustic signal that propagates into the earth and is at least partially reflected by subsurface seismic reflectors. The reflected signals are detected and recorded by an array of seismic receivers located at or near the surface of the earth, in an overlying body of water, or at known depths in boreholes.

[0004] During the data processing stage, the recorded seismic signals are refined and enhanced using a variety of procedures that depend on the nature of the geologic structure being investigated and on the characteristics of the raw data. In general, the purpose of the data processing stage is to produce an image of the subsurface from the recorded seismic data for use during the data interpretation stage.

[0005] The purpose of the data interpretation stage is to determine information about the subsurface geology of the earth from the processed seismic data. The results of the data interpretation stage may be used to determine the general geologic structure of a subsurface region, or to locate potential hydrocarbon reservoirs, or to guide the development of an already discovered reservoir.

[0006] At present, the conclusions which can be made after the data interpretation stage are generally limited to broad descriptions of the size and general nature of subsurface structures due to the limited resolution of seismic data. The descriptions may for example provide an indication of the total volume of hydrocarbons which might be retained in such structures. However, present technology does not allow the analyst to determine production rates from the subsurface formations if hydrocarbons are discovered. In addition, when an exploration well has been drilled, present technology does not allow an analyst to be able to accurately characterize the nature of the subsurface structure in locations other than in the most immediate region of any such well. Reservoir permeability and continuity, in particular, are not well characterized by present technology.

[0007] The hydrocarbon volume and rate of production depend on a variety of factors, including fluid properties, reservoir net-to-gross, porosity, permeability, spatial variability in grain size distribution, and continuity. Reservoir continuity, the communication (or lack thereof) between adjacent sand bodies, is commonly a primary factor controlling hydrocarbon production efficiency and ultimate recovery. There is a need to predict detailed internal structure of subsurface reservoirs using seismic data, and without having to drill many exploration and delineation wells. Such a capability would facilitate estimation of hydrocarbon volume in place and production rates early in the hydrocarbon exploration and development process. Accordingly, this invention satisfies that need.

#### SUMMARY OF THE INVENTION

[0008] A method for predicting the properties of a composite sedimentary body is disclosed. The method comprises (a) determining the outline form of the composite

body, (b) characterizing the local inlet properties of the fundamental bodies within the composite body, (c) determining the inlet location for the next fundamental body to be placed in the composite body outline, (d) placing the next fundamental body into the outline of the composite body, and (e) repeating steps (c) through (e) until the outline of the composite body is substantially full of fundamental bodies.

**[0009]** A second embodiment for a method for predicting the properties of a composite sedimentary body is disclosed. The method comprises (a) determining the outline form of the composite body, (b) determining the outline form of at least one fundamental body within the composite body, (c) determining the inlet properties of at least one fundamental body within the composite body, (d) characterizing the local inlet properties of the fundamental bodies within the composite body, (e) determining the inlet location for the next fundamental body to be placed in the composite body outline, (f) placing the next fundamental body into the outline of the composite body, (g) repeating steps (e) through (g) until the outline of the composite body is substantially full of fundamental bodies.

**[0010]** A third embodiment for a method for predicting the properties of a composite sedimentary body is disclosed. The method comprises (a) determining the outline form of the composite body, (b) measuring the thickness and grain size distribution at one point in at least one fundamental body within the composite sedimentary body, (c) determining the inlet properties of at least one fundamental body within the composite body from a point measurement of thickness and grain size distribution within the body, (d) characterizing the local inlet properties of the fundamental bodies within the composite body, (e) determining the inlet location for the next fundamental body to be placed in the composite body outline, (f) placing the next fundamental body into the outline of the composite body, (g) repeating steps (e) through (g) until the outline of the composite body is substantially full of fundamental bodies.

### BRIEF DESCRIPTION OF THE DRAWINGS

[0011] Figure 1 depicts the plan view boundaries and the velocity components of a fluid flow which may create a deposit;

[0012] Figure 2 depicts an elevation of the fluid flow of figure 1 and the elevation profile of the deposit that is created;

[0013] Figure 3 depicts a plan view of a multi-lobe water-lain sedimentary deposit;

[0014] Figure 4 is a flow chart of a first embodiment of the invention;

[0015] Figure 5 is a flow chart of a second embodiment of the invention;

[0016] Figure 6 is a flow chart of a third embodiment of the invention.

### DETAILED DESCRIPTION

[0017] In the following detailed description, the invention will be described in connection with its preferred embodiments. However, to the extent that the following description is specific to a particular embodiment or a particular use of the invention, this is intended to be illustrative only. Accordingly, the invention is not limited to the specific embodiments described below, but rather, the invention includes all alternatives, modifications, and equivalents falling within the true scope of the appended claims.

[0018] The present invention is a method for constructing a geologic model of a subsurface hydrocarbon reservoir made up of composite sedimentary bodies using seismic data and, if available, a minimum number of well penetrations. The geologic model thus created specifies the grain size distribution at all points internal to the composite body and identifies properties of the fundamental sedimentary bodies within the composite based on the outline form of the composite body and outlines of some of the fundamental bodies or available well penetrations. Fundamental bodies are defined as generally lobate sand bodies deposited during single flows, or multiple flows where the locus of deposition has remained relatively stationary. Composite

bodies are formed by aggregates of fundamental bodies together with adjacent fine-grained sediments that may form barriers to hydrocarbon flow.

[0019] The deposition of clastic sedimentary bodies typically begins with a flow of sediment-laden water from a confined channel, such as a river mouth, into an open region, such as a basin. Initially such flows expand freely and deposit sediment as the flow decelerates. Thereafter, as the deposited sediment grows in height, the deposit begins to obstruct the flow field. Eventually, the deposit becomes sufficiently large that the flow is diverted around it. This terminates construction of the deposit (fundamental body) and results in a new path for the flow to an open region beyond or adjacent to it. The deposition process then repeats, and a second fundamental body in the system is created. In addition, more than one such fundamental sedimentary body may be actively built within the system at a time. Overall, the process produces a composite sedimentary body consisting of stacks of fundamental sedimentary bodies, which is a useful model for the structure of hydrocarbon reservoirs.

[0020] Each fundamental body within the depositional system has an associated local inlet, the point at which the flow building the body ceases to be confined and becomes free to expand, as at the end of a channel or a local expansion point within a channel. The properties of the body are largely controlled by the properties of the depositing flow at the local inlet. Additionally, the parameters of the channel supplying the flow to the body and the degree to which the depositing flow erodes sediment within the channel and below the new body are largely determined by the flow properties at the local inlet.

[0021] In the present invention, the applicants recognized that if the locations, order of creation, and flow properties at the local inlets of the fundamental bodies within a composite body could be determined, then an accurate geologic model of composite could be constructed. The applicants further recognized that principles of fluid mechanics and sediment transport, combined with reasonable assumptions about correlation between and spatial variability of local inlet properties, allow the local inlet properties within a composite body to be characterized, at least statistically. This



characterization of local inlet properties throughout the composite body allows a geologic model to be constructed of the system.

**[0022]** The flow properties associated with a fundamental body include flow velocity, suspended sediment volume fractions, deposition time, and flow height. The properties of the body itself include, in addition to the flow properties associated with deposition, the thickness of the sediment body, the size of the body, the shape of the body, and the grain size distribution at each point within the body.

**[0023]** In the present invention, the applicants recognized that the local inlet properties for all fundamental bodies within one system may be approximately described by a single parameter which in turn controls the size, shape, and internal grain size distribution of the bodies. The flow velocity, flow height, and supplied grain size distribution at the inlet of each body is sufficient to determine the size, shape, and internal grain size distribution within the body. These inlet conditions may be considered to be a function of a single parameter. The single free parameter may be taken to be the flow velocity, the flow height, the inlet Froude number, or any function of those three. When the single parameter is determined, the remaining inlet conditions may be calculated. In this embodiment of the invention, the inlet flow velocity is selected as the unknown or free parameter. Assumptions which allow all inlet properties to be determined from the inlet flow velocity are explained in greater detail in co-pending U.S. patent application 60/466,655, but are summarized here: (a) that the size distribution of grains in the flow is known, (b) that the total volume of suspended sediment at the inlet is the maximum carrying capacity of the flow, so that the deposition rate is substantially zero at the inlet but becomes non-zero with an infinitesimal decrease in flow velocity, and (c) that empirical relations giving flow height and width as a function of flow velocity for flows in channels apply at the inlet location.

**[0024]** The applicants recognized that the inlet flow velocities of neighboring bodies within a system are drawn from the same statistical distribution and that the parameters of this distribution vary predictably with local inlet location in the depositional system. Thus, the statistical distribution of inlet flow velocities

throughout a depositional system can be characterized by determining the parameters of the distribution (such as mean and standard deviation) and the trend by which these parameters vary with location in the system. Two embodiments are identified for assessing the distribution and trends. One embodiment uses the outline of those fundamental bodies which may be detectable within a composite body. A second embodiment uses at least one core from a well penetration of the composite body along with the outline form of the composite body.

[0025] Figures 1 and 2 define certain parameters, which will assist in fully appreciating the present inventive method. The method is built on the assumption that the sediment, both in the flow and in the deposit, may be characterized by bins of a common nominal grain diameter. Each such bin may, for example, be characterized by a nominal diameter  $d_i$ , and include grains having an actual diameter with typical ranges from 84% to 119% of  $d_i$ . Other bin range definitions are within the scope of the present invention. The sediment grains are deposited from a sediment laden fluid flow immediately above the deposit, where that fluid flow has a height  $h(x,y)$ ,  $x$  and  $y$ -velocity components  $u(x,y)$  and  $v(x,y)$ , respectively. The velocity components are assumed to be constant with depth within the fluid flow. The quantity of sediment in the fluid flow may be defined by a vertically averaged volume fraction  $C_i(x,y)$  of grains in the  $i$ th grain size bin.

[0026] Figure 1 depicts a plan view of a fluid flow 10, with assumed boundaries 12 and 14, in an  $(x,y)$  coordinate system. At any given point within flow 10, the  $x$  and  $y$  velocity components are  $u(x,y)$  and  $v(x,y)$  respectively. As depicted in elevation view Figure 2, the height of fluid flow 10 at any point is given by  $h(x,y)$ , and the thickness of the deposit at any given point is given by  $z(x,y)$ . Deposit thickness  $z(x,y)$  results from grains in fluid flow 10 depositing from fluid flow 10 over a time duration  $T$ . After time  $T$ , the deposit is assumed to have grown sufficiently large that it diverts the flow that was building it, terminating growth of the deposit. The diverted flow then begins building another deposit in a different location. Figure 3 shows the mapview outline of a composite sedimentary body 30 and the mapview outlines of two smaller fundamental sedimentary bodies 32 within the composite. The inlet of the composite body 34 and the local inlets of the fundamental bodies 36 are also

indicated. Channels, 38, bring the flow from the inlet of the composite body to the local inlets of the fundamental bodies.

**[0027]** A first embodiment of the present invention will now be described, as shown in Figure 4. The first step (step 401) is to determine the outline form of the composite body. The second step (step 402) is to characterize the local inlet properties of the fundamental bodies within the composite body. The third step (step 403) is to determine the location within the composite body outline to place a fundamental body. The fourth step (step 404) is to place the fundamental body at the location determined in step 403. The fifth step (step 405) is to repeat steps 403 and 404 until the outline form of the composite body is substantially full of fundamental bodies. The inlet properties associated with the fundamental body include flow velocity at the inlet, flow height at the inlet, width of the inlet, and suspended sediment volume fractions in each grain size range at the inlet. The properties of the fundamental bodies include the outline form of the body, the grain size distribution at each point within the body, the flow field that built the body. The flow field that built the body--including the flow velocity, flow height, and suspended sediment volume fractions for each grain size range at each point in the depositing flow, and the geometry and fill properties of the channel that conducted the depositing flow from the composite body inlet to the local inlet of the fundamental body.

**[0028]** **Step 401:** Determine the outline form of the composite body. In one embodiment this is accomplished by identifying stratigraphic surfaces of the same order that bound, above and below, the composite body. Preferably, the stratigraphic surfaces extend to the edges of the composite body and close at the edges, though this is not a requirement of the method and partial outlines of composite bodies can be used. Methods for identifying stratigraphic surfaces in three-dimensional seismic volumes are familiar to persons of ordinary skill in the art, who will also recognize other equivalent methods for identifying or inferring the outline form of composite bodies. Such other methods include interpretation of two-dimensional seismic lines, other remote imaging techniques, correlating well logs, and spatially correlated outcrop observations. These other methods are also within the scope of this invention.

**[0029] Step 402:** Characterize the local inlet properties of the fundamental bodies within the composite body. In this embodiment, this characterization involves determining (a) the statistical distribution of local inlet properties at a point within the composite body, and (b) how this statistical distribution changes with local inlet position throughout the composite body. The inlet properties characterized in this step would be: the flow velocity at the inlet, the flow height at the inlet, volume fraction of the flow at the inlet composed of grains within each grain size range, inlet width, and the variability of all these properties with local inlet location in the system.

**[0030]** In co-pending U.S. patent application no. 60/466,655, assumptions are made about relationships between inlet flow properties. In one embodiment, flow velocity becomes the only independent variable in defining the local inlet properties. Thus, in that embodiment, characterizing the local inlet properties throughout the composite body can be accomplished by simply characterizing the local inlet flow velocity. Typically, the inlet flow velocity trend would be one of exponential decay in local inlet velocity with interpreted downstream distance from the composite body inlet, and the probability distribution would be assumed to be log-normal around the peak likelihood specified by the trend. This trend and probability distribution in local inlet velocity is then fully described by three parameters: the local inlet velocity at a point, the characteristic length of the exponential decay, and the standard deviation (on a logarithmic scale) of the log-normal distribution. Methods for estimating the parameters of such a model given a set of point determinations of local inlet properties are familiar to persons of ordinary skill in the art with the benefit of the disclosure of that application.

**[0031]** The estimation of parameters of a model describing the variability of inlet properties within the system requires actual estimates of inlet properties in at least one location within the system. Persons of ordinary skill in the art, with the benefit of the disclosures in co-pending U.S. provisional patent applications 60/466,655, 60/459,144 and 60/454,516 will recognize a variety of methods that could be used to provide inlet properties for particular sand bodies identified in seismic data or by well penetrations. These methods are intended to be within the scope of this invention.

**[0032] Step 403:** Determine the location in the composite body outline where the next fundamental body will be placed. One embodiment for determining the placement of bodies is given below. Persons of ordinary skill in the art will identify other embodiments that could be used which are also within the scope of the invention. The priority of placement is: bodies observed in seismic will be placed first (by order of proximity to the system inlet), followed by bodies detected in wells (working from the bottom of the well up to the top), followed by bodies constructed simply based on inlet property statistics. For bodies observed in seismic, the location is already determined. For bodies detected in wells, the location of the inlet is constrained by the requirement that the appropriate thickness contour of the deposit intersect the well.

**[0033]** The primary (downstream) axis of the fundamental body is further constrained to lie on a radial line from the system inlet. Subject to these constraints, the local inlet is placed as close as possible to the composite body inlet without causing the composite body model to exceed the observed thickness of the composite body by more than a prescribed percentage at any location--the prescribed percentage is typically 25% of the body thickness at the same location. Fundamental bodies constructed based on inlet property statistics are assumed to have primary axes (and inlets) along radial lines from the composite body inlet. The first such body is placed with its local inlet at the composite body inlet. Thereafter, each new local inlet is positioned as close as possible to the composite body inlet without causing the composite body model to exceed the observed thickness of the composite body by more than the prescribed percentage.

**[0034] Step 404:** Place the fundamental body in the system outline. For bodies observed in seismic or in wells, the inlet properties are already determined. For bodies to be generated randomly, the inlet properties are chosen at random, based on the probability distribution for inlet properties at the location of the local inlet point.

**[0035]** In one embodiment of this method, the sand body properties for the full range of inlet conditions are pre-calculated and stored for reference in computer memory. For a given set of inlet properties, the sedimentary body properties may be

determined by modeling the depositing flow using the local inlet properties as boundary conditions. Appropriate equations and methods for such modeling are described in co-pending U.S. provisional patent application no. 60/466,655, where vertically-averaged equations for conservation of momentum, flow volume, and sediment volume are identified for a steady-state flow, and the deposit height is inferred from the inlet conditions based on the assumption that the deposit grows until it is large enough to divert the flow that formed it.

**[0036]** In many systems, when the flow velocity drops to near zero, very fine-grained material rains down, creating shale drapes of large lateral extent. These can create barriers to hydrocarbon flow in subsurface reservoirs unless they are penetrated by erosion, breached by faulting, connected through injection of sand-filled dikes or other geologic processes. In as much as the depositing flow is known for each fundamental body, the degree to which that flow erodes into underlying sediment can also be calculated for each fundamental body as it is placed in the geologic model. An approximate method for capturing much of the effect of basal erosion on reservoir permeability is described here. A small thickness of shale is assumed to be deposited over the whole system prior to the activation of each new local inlet. The fundamental body properties pre-calculated for each inlet then include both the properties of the new sands deposited, and the maximum thickness of underlying sediment that can be removed.

**[0037]** After the sand is deposited, a channel is cut through the simulated system from the local inlet directly back to the system inlet. The channel may be assumed to be of rectangular aspect, having a depth equal to the inlet flow height, and a width equal to the inlet width. The sediment "removed" by this incision would then be uniformly mixed and redistributed to fill the volume of the incision. Optionally, the channel cut could be refilled with sediment having other properties if those properties are known.

**[0038]** **Step 405:** Repeat steps 403 and 404 until the simulated system is substantially filled with sedimentary bodies.

**[0039]** A second embodiment of the present invention will now be described as shown in Figure 5. The first step (step 501) is to determine the outline form of the composite body. The second step (step 502) is to identify the outline forms of all detectable fundamental bodies within the system. The third step (step 503) is to determine the local inlet properties of the detectable bodies. The fourth step (step 504) is to infer the statistical distribution of local inlet properties and variability in the parameters of this distribution with position in the system. The fifth step (step 505) is to determine the local inlet location for the next fundamental body. The sixth step (step 506) is place the simulated fundamental body into the outline form of the composite body. The seventh step (step 507) is to repeat steps 505-506 until the outline form of the composite body is substantially full of fundamental bodies. The inlet properties associated with the fundamental body include flow velocity at the inlet, flow height at the inlet, width of the inlet, and suspended sediment volume fractions in each grain size range at the inlet. The properties of the fundamental bodies include the outline form of the body, the grain size distribution at each point within the body, the flow field that built the body--including the flow velocity, flow height, and suspended sediment volume fractions for each grain size range at each point in the depositing flow, and the geometry and fill properties of the channel that conducted the depositing flow from the system inlet to the local inlet of the body.

**[0040]** **Step 501:** Determine the outline form of the composite body. In one embodiment this is accomplished by identifying stratigraphic surfaces of the same order that bound, above and below, the composite body. Preferably, the stratigraphic surfaces extend to the edges of the composite body and close at the edges, though this is not a requirement of the method and partial outlines of composite bodies can be used. Methods for identifying stratigraphic surfaces in three-dimensional seismic volumes are familiar to persons of ordinary skill in the art, who will also recognize other equivalent methods for identifying or inferring the outline form of composite bodies. Such other methods include interpretation of two-dimensional seismic lines, other remote imaging techniques, correlating well logs, and spatially correlated outcrop observations. These other methods are also within the scope of this invention.

**[0041] Step 502:** Identify the mapview outlines of at least fundamental bodies within the composite body. This identification is typically made in the same three-dimensional seismic volume used to identify the composite body outline. The method of picking these smaller units is typically based on contours of seismic amplitude, but persons of ordinary skill in the art will recognize other methods for picking stratigraphic units near the resolution limits of seismic data. Automated tools have been described to assist in this process, for example, in co-pending U.S. provisional patent application no. 10/395,911. Interpreted lines of three-dimensional seismic data, other remote imaging techniques, correlating well logs, and spatially correlated outcrop observations could also be used to identify outlines of fundamental bodies within the composite body. These other methods are also within the scope of this invention.

**[0042] Step 503:** Determine the local inlet properties for the observed bodies. One method is specified in co-pending U.S. provisional patent application no. 60/466,655. In this method, the seismic interpreter provides general paleocurrent directions sufficient to identify a local inlet point and down-stream end point for each identified seismic body. The method then utilizes constraints from fluid mechanics and conservation principles to relate a mapview contour of constant deposit thickness to the inlet properties of the flow that built the deposit.

**[0043] Step 504:** Estimate the trend in inlet properties and the probability distribution around this trend. As described in step 402, the inlet flow velocity trend is typically one of exponential decay with interpreted downstream distance from the composite body inlet, and the probability distribution could be log-normal around the peak likelihood specified by the trend. This trend and probability distribution in local inlet velocity is then fully described by three parameters: the local inlet velocity at a point, the characteristic length of the exponential decay, and the standard deviation (on a logarithmic scale) of the log-normal distribution. These parameters may be estimated from the local inlet properties determined for the identified fundamental bodies.

**[0044] Step 505:** This step is the same as step 403 in Figure 4.



**[0045] Step 506:** This step is the same as step 404 in Figure 4.

**[0046] Step 507:** Repeat steps 505-506 until there are no locations for new local inlets available within the simulated system.

**[0047]** A third embodiment of the present invention will now be described as shown in Figure 6. The first step (step 601) is to determine the outline form of the depositional system. The second step (step 602) is to identify the thickness and grain size distribution in at least one core that samples sedimentary bodies within the system. The third step (step 603) is to determine the inlet properties of the sampled bodies. The fourth step (step 604) is to infer the statistical distribution of inlet properties and variability in the parameters of this distribution with position in the system. The fifth step (step 605) is to determine the local inlet location for the next fundamental body. The sixth step (step 606) is to place the simulated fundamental body into the outline form of the composite body. The seventh step (step 607) is to repeat steps 605-606 until the outline form of the depositional system is substantially full of sedimentary bodies. The inlet properties associated with the sediment body include flow velocity at the inlet, flow height at the inlet, width of the inlet, and suspended sediment volume fractions in each grain size range at the inlet. The properties of the sedimentary bodies include the outline form of the body, the grain size distribution at each point within the body, the flow field that built the body--including the flow velocity, flow height, and suspended sediment volume fractions for each grain size range at each point in the depositing flow, and the geometry and fill properties of the channel that conducted the depositing flow from the system inlet to the local inlet of the body.

**[0048] Step 601:** This step is the same as step 401 in Figure 4.

**[0049] Step 602:** Measure the thickness and grain size distribution for at least one fundamental body penetrated by a core sampling the system.

**[0050] Step 603:** Determine the local inlet of the measured bodies. One method for making this determination is described in co-pending U.S. provisional patent application no. 60/459,144. In one embodiment, this method involves (a) estimating

flow properties at the location where the well penetrates each body, (b) extrapolating these flow properties back to the inlet location (identified as the point where the flow properties become consistent with flow in a channel), and (c) adjusting the initial flow property estimate until the extrapolated inlet flow properties are consistent with the extrapolated maximum height of the body. Applying this method to sand bodies that the well penetrates within the system gives inlet properties for bodies in the vicinity of the well.

**[0051] Step 604:** Estimate the trend in inlet properties and the probability distribution around this trend. As described in step 402, the inlet flow velocity trend is typically one of exponential decay with interpreted downstream distance from the system inlet, and the probability distribution could be log-normal around the peak likelihood specified by the trend. This trend and probability distribution in local inlet velocity is then fully described by three parameters: the local inlet velocity at a point, the characteristic length of the exponential decay, and the standard deviation (on a logarithmic scale) of the log-normal distribution.

**[0052]** Local inlet properties were calculated in step 603 for bodies in the vicinity of the well. If only one well is available, then it may not provide information about the trend of those properties throughout the system. One method for determining the trend in inlet properties throughout the system uses the relationship between system thickness and vertically averaged grain size distribution, as described in co-pending U.S. provisional patent application no. 60/454,516. The vertically averaged grain size distribution at a point in the system will be approximately equal to the average thickness-weighted grain size distribution in the typical sand body at that location. To determine the inlet properties of the typical sand body at a given location, the following method may be used: (a) determine the vertically averaged grain size distribution at that location by the method of co-pending U.S. provisional patent application no. 60/454,516. (b) guess the typical inlet velocity at that location. (c) calculate the other inlet properties based on the inlet velocity. (d) simulate the sand body outline and grain size distribution associated with the inlet properties. (e) calculate the average thickness-weighted grain size distribution within the body. (f) refine the inlet velocity estimate in step (b) until the average thickness-weighted grain

size distribution within the body is substantially equal to the vertically averaged grain size distribution for the system at that location as predicted in step (a). This method provides the inlet property trends directly from the shape of the composite body, without the need for observations of fundamental bodies at separate mapview locations.

**[0053] Step 605:** Step 605 is the same as step 403 in Figure 4.

**[0054] Step 606:** Step 606 is the same as step 404 in Figure 4.

**[0055] Step 607:** repeat steps 605-606 until there are no locations for new local inlets available within the simulated system.

We claim:

1. A method for predicting the properties of a composite sedimentary body, comprising:

- (a) determining the outline form of the composite body;
- (b) characterizing the local inlet properties of the fundamental bodies within the composite body;
- (c) determine the inlet location for the next fundamental body to be placed in the composite body outline.
- (d) place the next fundamental body into the outline of the composite body.
- (e) repeat steps (c) through (e) until the outline of the composite body is substantially full of fundamental bodies.

2. The method of claim 1, wherein the local inlet properties are chosen from the group comprising: flow velocity at the inlet, flow height at the inlet, suspended sediment volume within at least one grain size range, inlet width, flow duration, inlet location, order in which said inlet is active relative to other local inlets within the depositional system, and any combination thereof.

3. The method of claim 1, wherein the properties of the fundamental body are chosen from the group comprising: shape of the body, size of the body, height of the body, grain size distribution in at least one point within the body, bedding type in at least one point within the body, degree of erosional scour below the body associated with deposition of the body, shape of the channel feeding sediment to the inlet, size of the channel feeding sediment to the inlet, degree of erosional scour caused by the channel feeding sediment to the inlet, at least one property of sediment which forms

the channel feeding sediment to the inlet, at least one property of sediment which subsequently fills the channel feeding sediment to the inlet, and any combination thereof.

4. The method of claim 1, wherein the outline form of the composite body is determined from seismic data.

5. The method of claim 1, wherein the inlet properties are determined using grain size and body thickness measurements from a well sample of at least fundamental body within the composite body.

6. The method of claim 1, wherein the inlet properties are determined using the outline form of at least one fundamental body.

7. The method of claim 1, wherein lateral variability in the inlet properties within the composite body is determined using the outline form of the composite body.

8. The method of claim 1, wherein the characterizing the local inlet properties involves determining statistical distributions of the inlet properties.

9. The method of claim 1, wherein the possible range of the inlet properties is constrained by mathematical relationships between at least two of the inlet properties.

10. A method for predicting the properties of a composite sedimentary body, comprising:

(a) determining the outline form of the composite body;

(b) determining the outline form of at least one fundamental body within the composite body;

(c) determining the inlet properties of at least one fundamental body within the composite body;

(d) characterizing the local inlet properties of the fundamental bodies within the composite body;

(e) determine the inlet location for the next fundamental body to be placed in the composite body outline.

(f) place the next fundamental body into the outline of the composite body.

(g) repeat steps (e) through (g) until the outline of the composite body is substantially full of fundamental bodies.

11. The method of claim 10, wherein the local inlet properties include are chosen from the group comprising: flow velocity at the inlet, flow height at the inlet, suspended sediment volume within at least one grain size range, inlet width, flow duration, inlet location, order in which said inlet is active relative to other local inlets within the depositional system.

12. The method of claim 10, wherein the properties of the fundamental body are chosen from the group comprising: shape of the body, size of the body, height of the body, grain size distribution in at least one point within the body, bedding type in at least one point within the body, degree of erosional scour below the body associated with deposition of the body, shape of the channel feeding sediment to the inlet, size of the channel feeding sediment to the inlet, degree of erosional scour caused by the channel feeding sediment to the inlet, at least one property of sediment which forms the channel feeding sediment to the inlet, at least one property of sediment which subsequently fills the channel feeding sediment to the inlet.

13. The method of claim 10, wherein the outline form of the composite body is determined from seismic data.

14. The method of claim 10, wherein the outline form of the fundamental body is determined from seismic data.

15. The method of claim 10, wherein the characterizing the local inlet properties involves determining statistical distributions of the inlet properties.

16. The method of claim 10, wherein the possible range of the inlet properties is constrained by mathematical relationships between at least two of the inlet properties.

17. A method for predicting the properties of a composite sedimentary body, comprising:

- (a) determining the outline form of the composite body;
- (b) measuring the thickness and grain size distribution at one point in at least one fundamental body within the composite sedimentary body;
- (c) determining the inlet properties of at least one fundamental body within the composite body from a point measurement of thickness and grain size distribution within the body;
- (d) characterizing the local inlet properties of the fundamental bodies within the composite body;
- (e) determine the inlet location for the next fundamental body to be placed in the composite body outline.
- (f) place the next fundamental body into the outline of the composite body.
- (g) repeat steps (e) through (g) until the outline of the composite body is substantially full of fundamental bodies.

18. The method of claim 17, wherein the local inlet properties are chosen from the group comprising: flow velocity at the inlet, flow height at the inlet, suspended sediment volume within at least one grain size range, inlet width, flow duration, inlet location, order in which said inlet is active relative to other local inlets within the depositional system.

19. The method of claim 17, wherein the properties of the fundamental body are chosen from the group comprising: shape of the body, size of the body, height of the body, grain size distribution in at least one point within the body, bedding type in at least one point within the body, degree of erosional scour below the body associated with deposition of the body, shape of the channel feeding sediment to the inlet, size of the channel feeding sediment to the inlet, degree of erosional scour caused by the channel feeding sediment to the inlet, at least one property of sediment which forms the channel feeding sediment to the inlet, at least one property of sediment which subsequently fills the channel feeding sediment to the inlet.

20. The method of claim 17, wherein the outline form of the composite body is determined from seismic data.

21. The method of claim 17, wherein the characterizing the local inlet properties involves determining statistical distributions of the inlet properties.

22. The method of claim 22, wherein the lateral variability in the inlet properties within the composite body is determined using the outline form of the composite body.

23. The method of claim 17, wherein the possible range of the inlet properties is constrained by mathematical relationships between at least two of the inlet properties.



**ABSTRACT**

The present invention is a method for constructing a geologic model of a composite sedimentary body. The fundamental sedimentary bodies within the composite body are specified by the properties of the flow which built them, particularly the flow properties at the local inlet of each body. The statistical distribution of these local inlet properties is characterized throughout the fundamental body using either outline forms of some of the fundamental bodies or a core which samples the composite body. The geologic model is constructed by placing an appropriate statistical distribution of the fundamental bodies into the outline form of the composite body, and provides a grain size distribution at each point within the composite body.

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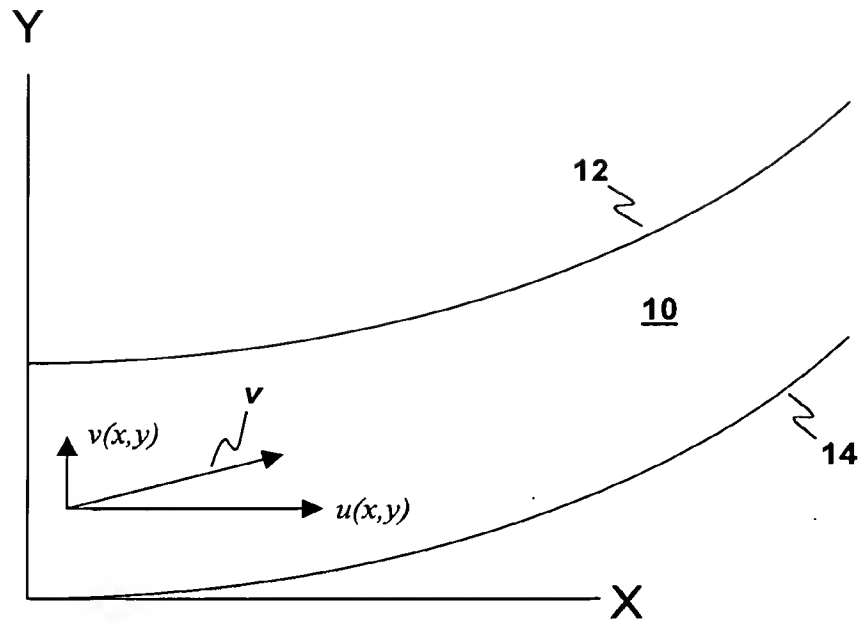


Figure 1

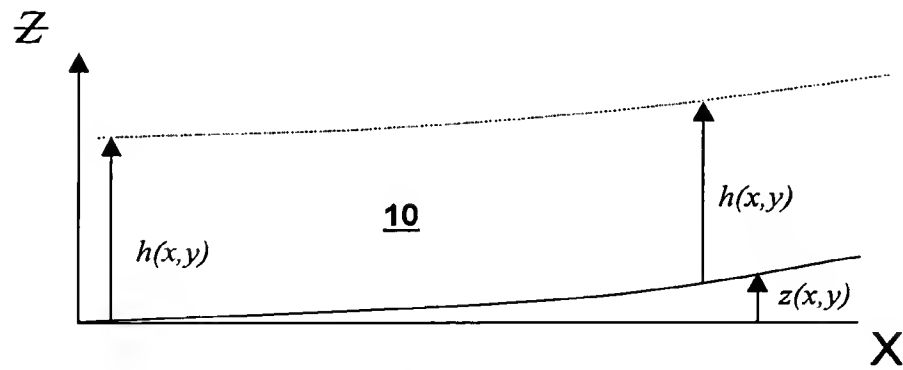


Figure 2

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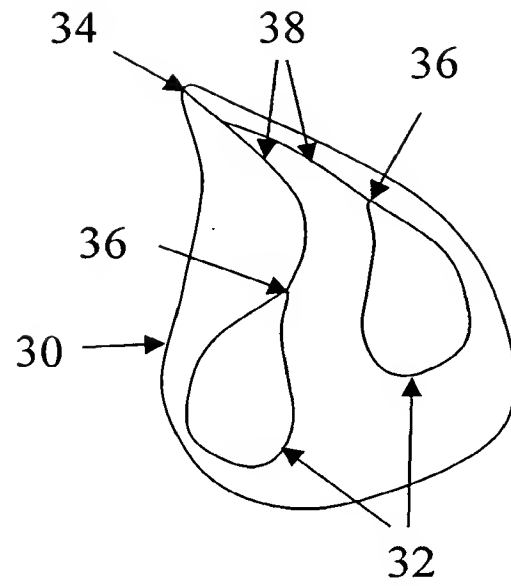
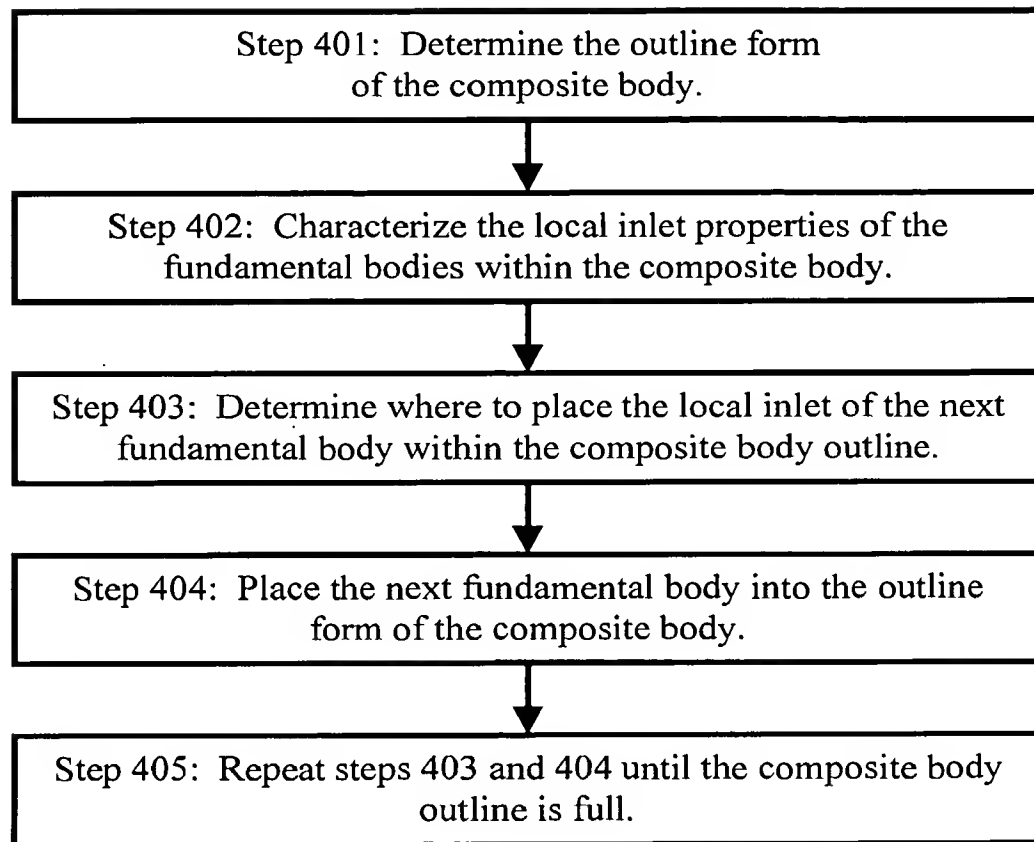
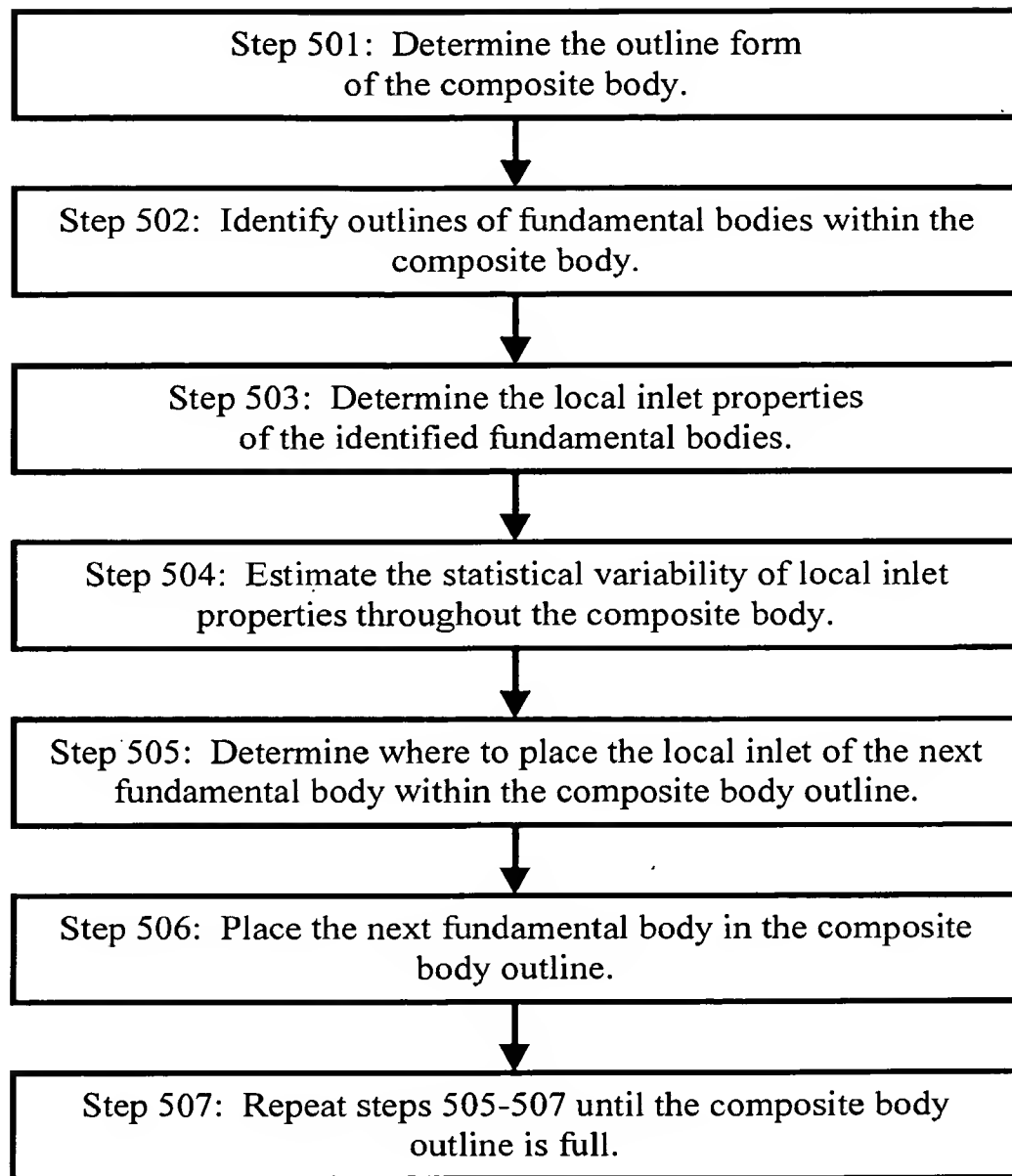
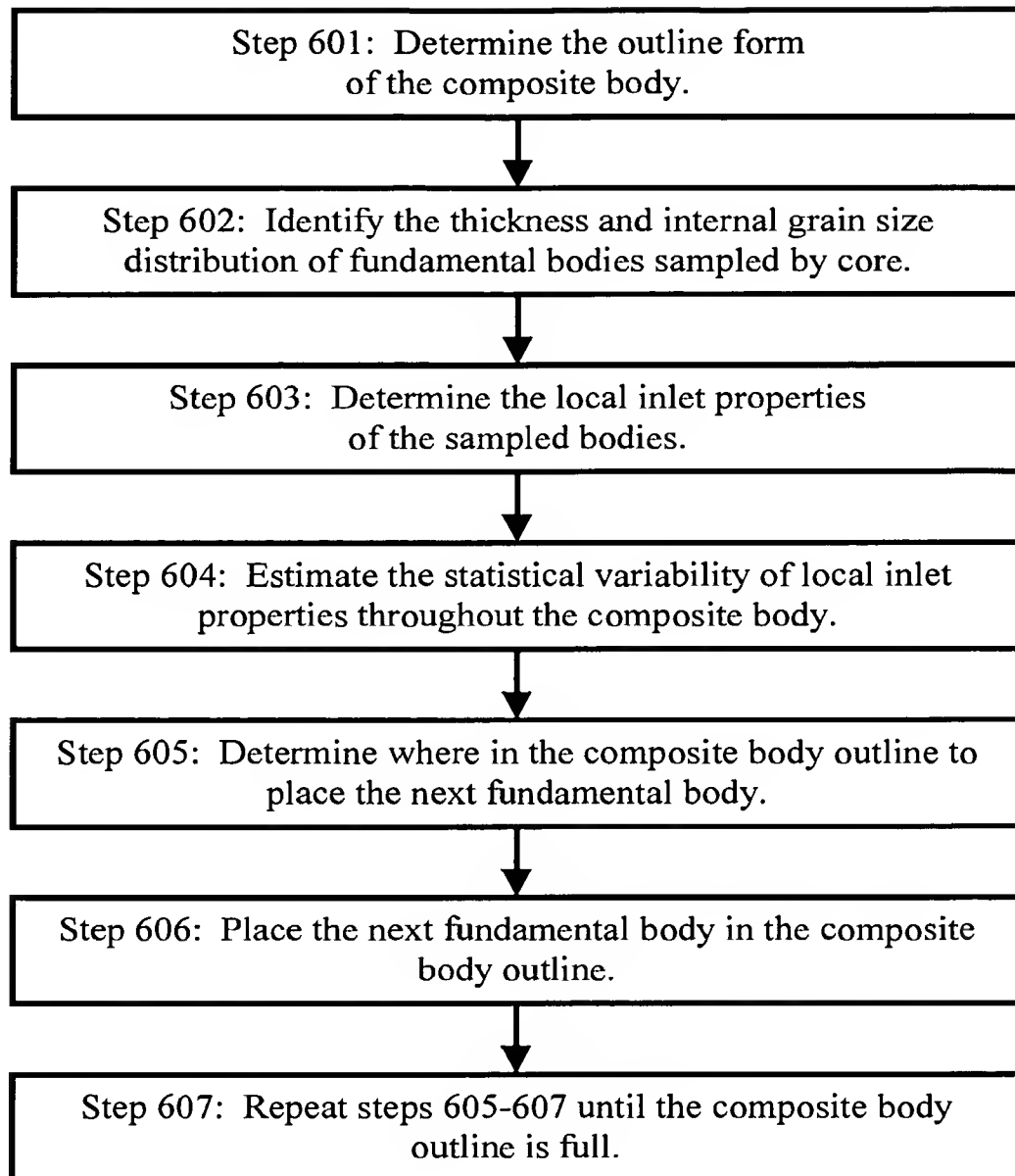


Figure 3

**3/5***Figure 4*

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*Figure 5*

**5/5****Figure 6**

## **Application Data Sheet**

### **Application Information**

Application number::  
Filing Date:: March 31, 2004  
Application Type:: Provisional  
Subject Matter:: Utility  
Suggested Classification:: /  
Suggested Group Art Unit::  
CD-ROM or CD-R?:: None  
Title:: METHOD FOR CONSTRUCTING A GEOLOGIC  
MODEL OF A COMPOSITE SEDIMENTARY BODY  
Attorney Docket Number:: 2003UR007  
Request for Early Publication?:: No  
Request for Non-Publication?:: No  
Suggested Drawing Figure:: 3  
Total Drawing Sheets:: 5  
Small Entity?:: No  
Petition included?:: No  
Secrecy Order in Parent Appl?:: No

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### Domestic Priority Information

Application::	Continuity Type::	Parent Application::	Parent Filing Date::
<b><i>This Application</i></b>	<i>Non-Provisional of</i>		

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